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PENSOFT

Species diversity of the genus *Riccia* L. (Marchantiales, Ricciaceae) in Maranhão state, Brazil

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Abstract
Ricciaceae is a little-known liverwort family in northeastern Brazil. Fieldwork in 4 localities in Maranhão state yielded 4 species of *Riccia*, with 2 taxa, *R. mauryana* and *R. weinionis*, representing new state records. This paper describes the species diversity of the genus *Riccia* in Maranhão state, and provides descriptions, ecological notes, and illustrations for each species.

Key words
Biodiversity; bryophytes; Cerrado; liverworts; Northeastern Brazil; riparian forest; taxonomy.

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Introduction

Riccia L. is the most species-rich genus within the order Marchantiales. It comprises approximately 150 species globally; 53 species occur in tropical America (Bischler-Causse et al. 2005) and 36 in Brazil (Costa and Peralta 2015), corresponding to 67% of the tropical American species of *Riccia* and 24% of the world species diversity (Söderström et al. 2016). Most species are terrestrial and occur in both natural and disturbed habitats (such as gardens and along trails), often on soil in open areas.

Studies on the genus *Riccia* in Brazil have been carried out by Vianna (1985), who treated the genus *Riccia* in a revision of the Marchantiales for Rio Grande do Sul State and reported 11 species; Gradstein and Costa (2003), who cited 29 species for Brazil and provided a key to all the species; Bischler-Causse et al. (2005), who treated 32 species of Brazil in the Flora Neotropica Monograph for Marchantiidae; and Ayub et al. (2014), who reported 22 species for Rio Grande do Sul State (including new records for Brazil and for that state).

It is estimated that 89 bryophyte species occur in Maranhão state (Costa and Peralta 2015), and about 715 in northeastern Brazil (Flora do Brasil 2017, under construction). There have been only a few studies published on the bryoflora of Maranhão state (Brito and Ilkiu-Borges 2012, 2014, Conceição et al. 2010, Costa et al. 2015, Macedo and Ilkiu-Borges 2014, Peralta et al. 2011, Santos and Conceição 2010, Varão et al. 2011, Yano et al. 2009), and just 2 cite species of *Riccia* (Varão et al. 2011, Peralta et al. 2011).

The northeastern region of Brazil is considered to have low bryophyte diversity, with their richness being concentrated in the Atlantic Rainforest area, in addition to a low endemicity rate (just 2 species: *Riccia erythro-*

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carpa Jovet-Ast and *R. subdepilata* Jovet-Ast) (Gradstein and Costa 2003).

There are only a few researchers involved in taxonomic revisions of liverworts in that country (e.g., Ayub et al. 2014, Bastos 2004, 2017, Costa 2008, Gradstein and Costa 2003, Gradstein 2015, Gradstein and Ilkiu-Borges 2015, 2018, Ilkiu-Borges 2016), but their studies are crucial for liverwort identifications in floristic inventories.

Eighteen species of *Riccia* (Flora do Brasil 2017, under construction) have been reported for northeastern Brazil based on floristic surveys such as Yano et al. (2009), Pôrto and Bezerra (1996), Silva and Pôrto (2014), and the taxonomic monographs provided by Jovet-Ast (1987, 1991) and Bischler-Causse et al. (2005).

Maranhão state includes fragments of the Amazonian, Caatinga (deciduous dry forests), and Cerrado (Neotropical savanna) biomes, as well as transitional zones between them, with *Cerrado* being the predominant biome (IBGE 2017). Currently, just 3 species of *Riccia* have been cited for that state, all of them known from many regions of Brazil: *R. stenophylla* Spruce, *R. vitalii* Jovet-Ast, and *R. planobiconvexa* Steph (see Jovet-Ast 1987, 1991, Bischler-Causse et al. 2005, Yano et al. 2009).

The present paper provides an overview of the genus *Riccia* for Maranhão state, incorporating new records into the liverwort flora and analyzing the distributions of those taxa, and represents the first effort directed towards filling in information gaps about this genus in northeastern Brazil.

Methods

Specimens were collected in 4 different municipalities: Anapurus and Chapadinha in eastern Maranhão state, and Carolina and Estreito in southern Maranhão state (Fig. 1). These municipalities are predominantly covered by Cerrado vegetation (Silva et al. 2008, IBGE 2017). Samples were collected mainly during the rainy season, between 2016 and 2017, following the methodology proposed by Yano (1989). The specimens were preserved in dry and wet form (*ex situ* in a greenhouse). Preserved specimens were subsequently deposited in the CCAA herbarium of the Federal University of Maranhão, with duplicates in herbarium RB at the Rio de Janeiro Botanical Garden.

The specimens were identified and the geographic distributions of the species determined using Gradstein and Costa (2003), Bischler-Causse et al. (2005), Peralta et al. (2011) and Flora do Brasil (2017).

Results

Riccia L., Sp. pl., ed. 1, 1138. 1753.

Thalli forked, in rosettes or gregarious patches, prostrate and dorsiventral, terrestrial or aquatic (floating), usually with a deep median groove, green, grayish-green, yellow-green or glaucous, ventral surface usually with scales and rhizoids. Ventral scales usually in 1-2 rows or absent, imbricate, lunulate, purple or hyaline, sometimes extending beyond the margins of the thalli. Epidermal region with air chambers in 1-3 layers. Monoecious or dioecious. Antheridia and archegonia scattered and embedded in the thallus, chambers open through ostioles. Capsule embedded in the thallus, disintegrating at maturity. Spores sometimes in tetrads, large, brown to black, distal and proximal faces with areoles, ridges, spines or smooth.

The species are delimited morphologically by characteristics of thalli (cross section), scales (color and arrangement), and spores (shape, ornamentation, size).

Key to the genus *Riccia* from Maranhão state

1 Plants semiaquatic; thalli forming partial rosettes; spores with 3–5 areolae on the distal face ..... ***R. stenophylla***

1′ Plants usually terrestrial; thalli forming rosettes or gregarious patches; spores with more than 5 areolae on the distal face 2

2 Scales large (0.05 mm), violaceous, imbricate, reaching beyond the lobe margins ..... ***R. vitalii***

2′ Scales small (0.01–0.02 mm), hyaline, imbricate, not reaching the lobe margins 3

3 Cells of dorsal tissue without thickened longitudinal strips ..... ***R. planobiconvexa***

3′ Cells of dorsal tissue thickened or with longitudinal strips 4

4 Cells of dorsal tissue with thickened walls; thalli margins hyaline; spores subspherical ..... ***R. mauryana***

4′ Cells of dorsal tissue with two longitudinal, thickened strips; thalli margins light-green or whitish; spores tetrahedral ..... ***R. weinionis***

1. *Riccia mauryana* Steph., Sp. Hepat. 1: 19. 1898. Figure 2A–C

Material examined. Brazil: Maranhão: Chapadinha, Capitão de Campo, periodically flooded area, partly exposed to the sun, 03°44′30″ S, 043°21′37″ W, 105 m a.s.l., M.A.F. Rodrigues and A.L.F. Rodrigues, 21 May 2016, 52 (CCAA); Chapadinha, pavement border of the Centro de Ciências Agrárias e Ambientais da Universidade Federal do Maranhão, 03°43′58″ S, 043°19′07″ W, 107 m a.s.l., J.A.S. Silva, 4 April 2017, 134 (CCAA).

Description. Thalli in gregarious patches, dorsal surface light to grayish-green and ventral surface pale-green to brownish, forked 2–3 times, lobes 5–15 mm long, 2–3 mm wide, rounded apically, margins narrow and hyaline, 2–3 cells wide, with a deep median groove. Epidermal cells green and ovate-rounded when intact, and lunulate when not intact; without pores. Ventral scales hyaline to rose, imbricate, lunulate. Lobes in cross section 2–6 times as wide as high, 0.6–0.8 mm high, dorsal margin acute, ascending or concave, recurved and acute; ventral margin convex; dorsal tissues with large cells in 5–7 cell layers, with thickened walls or with thick and

longitudinal hyaline strips. Spores subspherical, red-brown, ornamented, wingless, distal surface with 8–11 areolae, proximal face with incomplete areole, 60–100 µm diam.

Distribution and ecology. USA, Mexico, Brazil, Argentina (Bischler-Causse et al. 2005). A rare species, previously only known for Pernambuco State in Brazil; this is the first record for Maranhão state. In Maranhão,

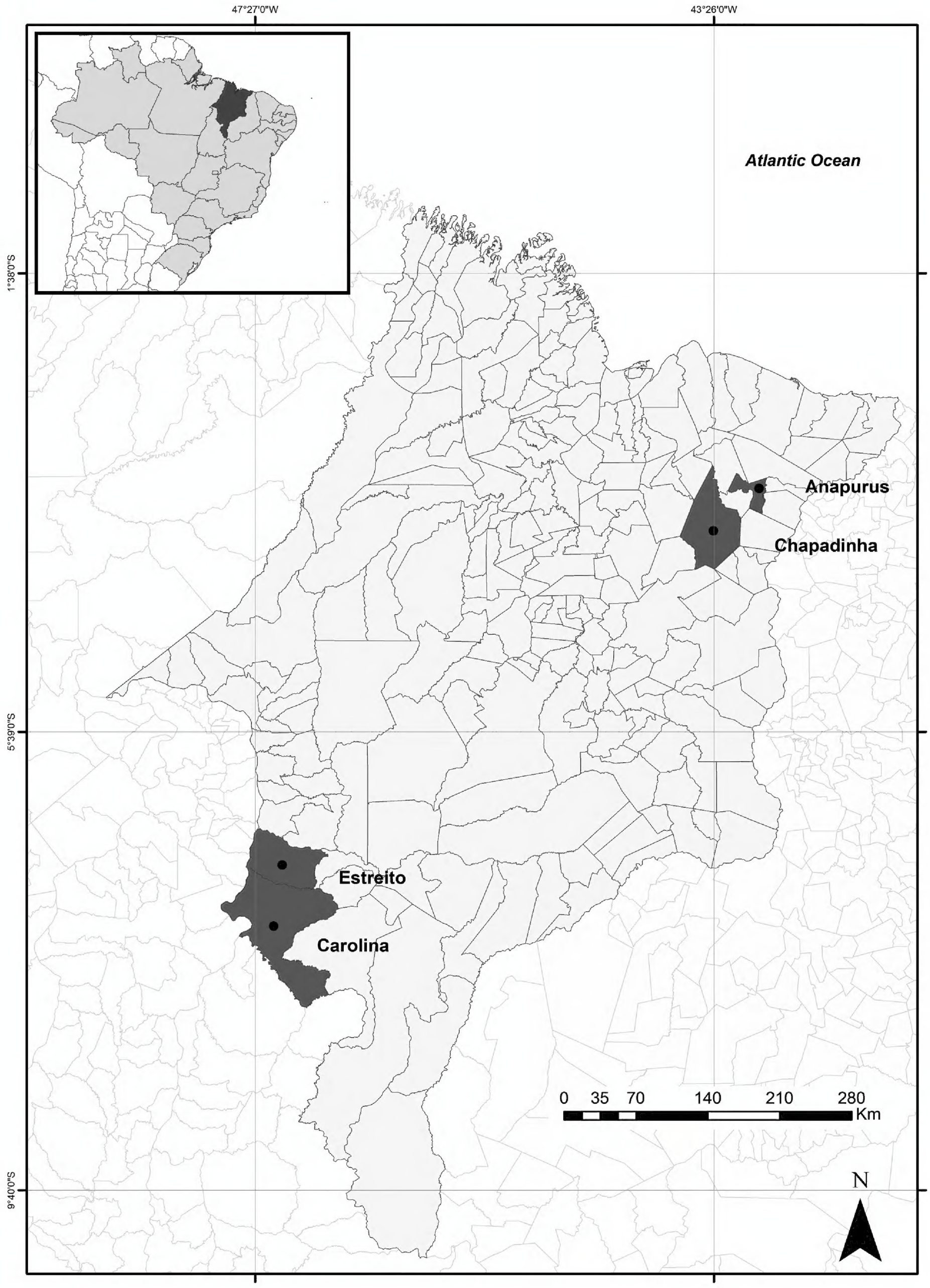

Figure 1. Map of Maranhão state, Brazil, indicating the localities sampled (source: Center for Scientific Computing/JBRJ).

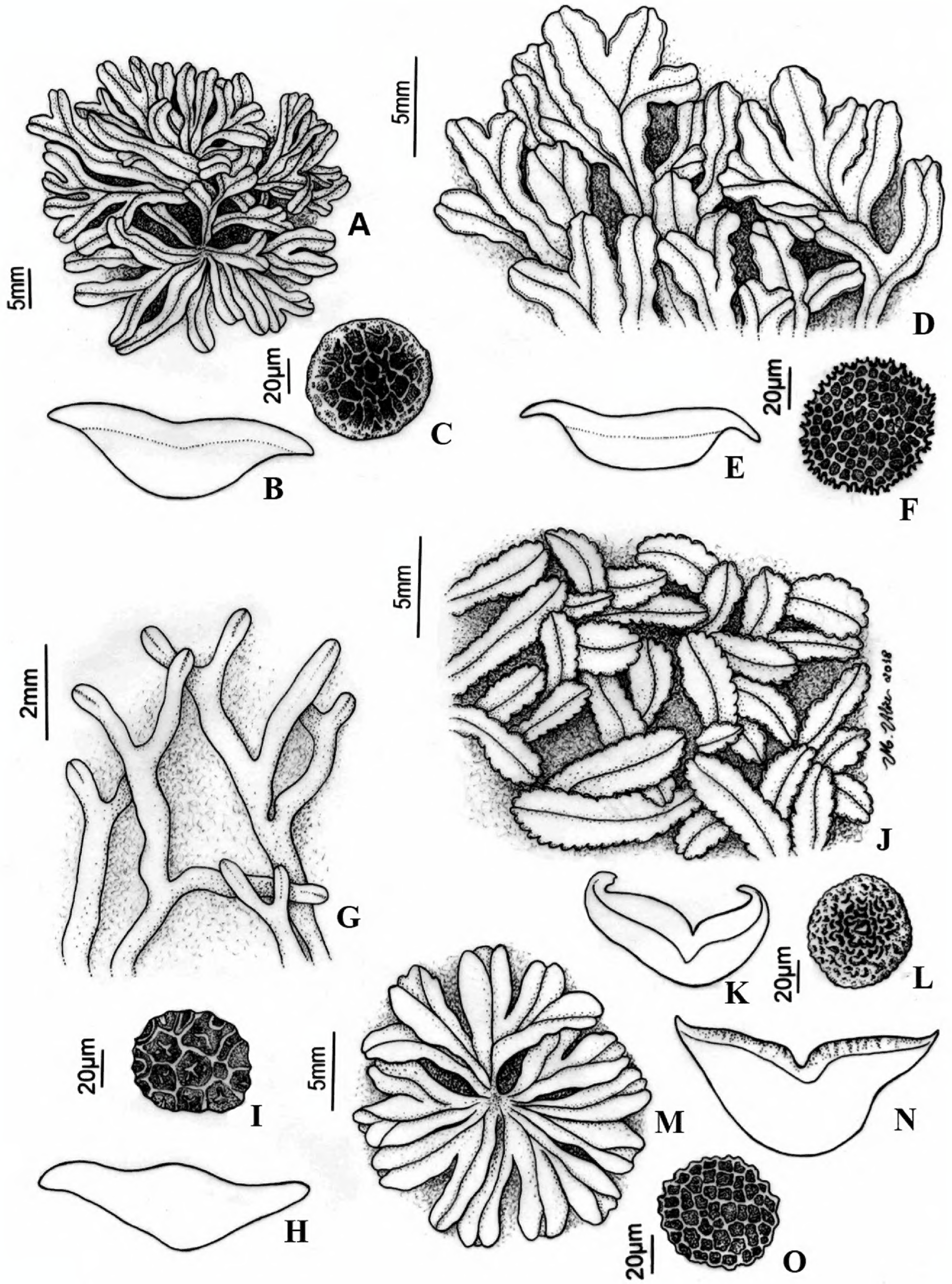

Figure 2. A–C. *Riccia mauryana*, A. thalli in gregarious patches, B. cross section of the thallus, C. spores **D–F.** *Riccia planobiconvexa,* D, thalli in gregarious patches, E. cross section of the thallus, F. spores **G–I.** *Riccia stenophylla,* G. thalli forming partial rosettes, H. cross section of the thallus, I. spores **J–L.** *Riccia vitalii*, J. thalli in gregarious patches, K. cross section of the thallus, L. spores **M–O.** *Riccia weinionis,* M. thalli forming rosettes, N. cross section of the thallus. O. spores. (**A–C.** *M. A. F Rodrigues and A.L.F. Rodrigues 52* (CCAA); **D–F.** *E.S. Brito 23* (SP); **G–I.** *M.A.F Rodrigues and A.L.F. Rodrigues 11*; **J–L** *J.A.S. Silva 85* (CCAA); **M–O.** *J.A.S. Silva 135* (CCAA). Illustrations: Maria Alice de Rezende.

it is usually found forming mats on limestone substrates (such as pavements), but forms rosettes on partially flooded sites. We observed scales varying in color depending on the degree of thallus decomposition and habitat humidity. In dry habitats, it is possible to observe scales more pinkish than hyaline, while in humid habitats the scales are always hyaline.

2. *Riccia planobiconvexa* Steph., Bih. Kongl. Svenska Vetensk.-Akad. Handl. 23: 29. 1897.
Figure 2D–F

Material examined. Brazil: Maranhão: Caxias, Auto Estevão, segundo distrito, solo (barranco), 04°51′32″ S, 043°21′22″ W, 66 m a.s.l., E.S. Brito, 17 June 2007, 23 (SP).

Description. Thalli in gregarious patches, dorsal surface light-green or greenish, ventral surface green, brownish or violaceous, forked 2–3 times, lobes 7–12 mm long, 3 mm wide, rounded apically, 3–4 cells wide, with a deep median groove, flattened and vanishing toward base. Epidermal cells disintegrating, without pores. Ventral scales hyaline, usually not reaching beyond the lobe margins. Lobe in cross section 3–5 times as wide as high, dorsal margin abruptly extending into thin wings, ending in a hyaline cell, ventral margin convex; dorsal tissue with 8–10 cell layers, thinner than the ventral layers, cells thin-walled and without longitudinal strips. Spores subspherical, red-brown, ornamented, wingless, distal surface with 8–11 areolae, proximal face similarly ornamented, with somewhat lower ridges and tubercles, triradiate scar indistinct, 70–130 µm diam.

Distribution and ecology. A Neotropical species recorded from Costa Rica, Ecuador (Galápagos Islands), Argentina and Brazil (Bischler-Causse et al. 2005). Quite common in Brazil, occurring in Alagoas, Bahia, Ceará, Distrito Federal, Espírito Santo, Goiás, Maranhão, Mato Grosso, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Santa Catarina, and Tocantins states.

3. *Riccia stenophylla* Spruce, Bull. Soc. Bot. France 36 (suppl.): 195. 1890.
Figure 2G–I

Material examined. Brazil: Maranhão: Chapadinha, Xororó, margin of ravine near stream, terrestrial, exposed to the sun, 03°44′30″ S, 043°21′37″ W, 105 m a.s.l., M.A.F Rodrigues and A.L.F. Rodrigues, 14 September 2016, 11 (CCAA)

Description. Thalli forming partial rosettes, dorsal surface light green and ventral surface pale green, forked 2–3 times, lobes 5–12 mm long, 0.2–0.4 mm wide, rounded apically, margins narrow and hyaline, 1–2 cells wide, median groove absent. Epidermal cells light green and rounded, with pores bounded by 4 cells. Ventral scales hyaline, conspicuous, semi-lunulate. Lobe in cross section 2–3 times as wide as high, 0.3 mm high, dorsal margin rounded or obtuse laterally, ventral margin convex, dorsal tissue with large cells, air chambers in 2–3 layers. Spores tetrahedral, brown or light red-brown, ornamented, distal face with 3–5 areolae, proximal face with evident triradiate scar, 65–80 µm diam.

Distribution and ecology. Widespread in tropical America (Bischler-Causse et al. 2005, Gradstein et al. 2016). Quite common and widespread in Brazil (in the states of Bahia, Ceará, Espírito Santo, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Paraíba, Paraná, Pernambuco, Rio Grande do Sul, Rio de Janeiro, Santa Catarina, and São Paulo). This species grows in abundant populations along the margin of ravines near water in Maranhão state, often being encountered partially submerged along stream margins.

4. *Riccia vitalii* Jovet-Ast, Mem. New York Bot. Gard. 46: 283. 1987.
Figure 2J–L

Material examined. Brazil: Maranhão: Carolina, Parque Nacional Chapada das mesas, near to Farinha river, right margin, rupicolous, exposed to the sun, 06°59′37″ S, 047°09′57″ W, 194 m a.s.l., J.A.S. Silva, 12 March 2017, 73, 75, 79 (CCAA); Estreito, Parque Nacional Chapada das Mesas, left bank of the river, on rocks in front of the waterfall, exposed to the sun, 06°59′39″ S, 047°09′56″ W, 192 m a.s.l., J.A.S. Silva, 12 March 2017, 85 (CCAA).

Description. Thalli in gregarious patches, dorsal surface pale or dark-green, ventral surface violet or pink-violet, forked 2–6 times, lobes 5–8 mm long, 2–4 mm wide, rounded apically, margins narrow and hyaline, 2–3 cells wide, with a deep median groove. Epidermal cells hyaline, convex, disintegrating except in groove, without pores. Ventral scales violaceous or pink, imbricate, extending beyond the lobe margins. Lobes in cross section 2–4 times as wide as high, dorsal margin ascending, erect, or oblique, ventral margin convex, dorsal tissue with large cells in 6–8 cell layers, cell layer below epidermis with 2 thickened longitudinal strips on the cell walls. Spores subspherical or sub-tetrahedral, dark red, or dark red-brown, ornamented, wingless, distal surface with 6–9 areolas, proximal face granulose with triradiate scar, 92–150 µm diam.

Distribution and ecology. Found in Costa Rica, Paraguay, Colombia and Brazil (Bischler-Causse et al. 2005, Gradstein et al. 2016). A widespread species in Brazil, occurring in all 5 regions (northern: Amazonas, Tocantins; northeastern: Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Sergipe; middle-western: Goiás, Mato Grosso do Sul; southeastern: Espírito Santo; southern: Paraná, Rio Grande do Norte, Rio Grande do Sul). It is quite common in Brazil and found on humid soils or rocky surfaces, forming large mats. When dry, the scales fold over the dorsal surface of the thallus – which is easily observed in the field and useful for distinguishing *R. vitalii* from other species of *Riccia*.

5. *Riccia weinionis* Steph., Sp. Hepat. 1: 18. 1898. Figure 2M–O

Material examined. Brazil: Maranhão: Anapurus, near balneário municipal, inside the riparian forest, terrestrial, 03°40′18″ S, 043°06′58″ W, 82 m a.s.l., J.A.S. Silva, 24 April 2016, 8, 19 (CCAA); Anapurus, povoado Formiga I, terrestrial, collected exposed to the sun, 03°40′17″ S, 043°07′09″ W, 82 m a.s.l., J.A.S. Silva, 15 April 2017, 135 (CCAA).

Description. Thalli forming rosettes, dorsal surface grayish-green or whitish when dry, green or blue-green when moist, ventral surface light-green, forked 2–4 times, lobes 10–12 mm long, 2–3 mm wide, rounded apically, margin narrow and hyaline, 2–3 cells wide, with a deep median groove. Epidermal cells hyaline, rounded, without pores. Ventral scales hyaline, distant, semi-lunulate, not reaching the lobe margins. Lobes in cross section 2–4 times as wide as high, 0.2–0.5 mm high, dorsal margins acute with short wings, ventral margins convex, dorsal tissue with 2–4 cell layers, cell walls with 2 longitudinal strips. Spores tetrahedral, red-brown to black-red, ornamented, wingless, distal face with 8–9 areolas, proximal face with few complete areolae, triradiate scar indistinct, 80–130 µm diam.

Distribution and ecology. Mexico, Costa Rica, Panama, West Indies, Colombia, and Brazil (Bischler-Causse et al. 2005). Quite common in Brazil (and widespread in the states of Ceará, Espírito Santo, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraíba, Paraná, Rio Grande do Sul, Rio de Janeiro, São Paulo, and Sergipe), growing on soils rich in organic matter and well-drained; its thalli are blue to green colored when fresh. This is the first record for Maranhão state, where it was encountered associated with *Notothylas vitalii* Udar and Singh, growing in open areas within riparian forest.

Discussion

Riccia is the largest genus among the thallose liverworts in Brazil (Gradstein and Costa 2003, Ayub et al. 2014) and is currently represented in Maranhão state by 5 species, 2 of which are reported here for the first time, *Riccia mauryana* and *R. weinionis*, enlarging the distribution of the species. The taxa were found in several localities, occurring on soil and in disturbed habitats such as sidewalks or open areas.

The species sampled and described in this paper are all from the Cerrado Biome, and likely represent only a small portion of the bryophyte diversity of Maranhão, a state which occurs in the transitional zones between 3 different Brazilian biomes (Amazonian, Caatinga, and Cerrado). *Riccia* has its highest diversity often observed in areas with dry seasons (Bischler-Causse et al. 2005), such as the Cerrado. Beside this, according to Jovet-Ast (1991, 1993), species distributions are still incomplete because of the strong seasonality (disappearing during the dry season) of the species. Most of the studies and collection efforts in the state focused in the Cerrado biome (see Conceição et al. 2010, Santos and Conceição 2010, Peralta et al. 2011, Varão et al. 2011, speciesLink Network 2018). Therefore, information from other biomes in the state are scarce, and the genus is probably sub-sampled. Thus, additional floristic and taxonomic studies related to the genus will still be necessary in different under-collected regions of the state, including in the Amazonian and Caatinga biomes from where few collections are currently held in the Brazilian herbaria (speciesLink Network 2018).

Collecting in these 2 biomes will almost certainly add new records to the liverwort bryoflora of Maranhão state. The Caatinga biome is unique to Brazil and very distinct from the Amazonian and Atlantic Forest biomes. We expect to find *Riccia* species in the Caatinga biome because of its semiarid climatic conditions including high temperatures and high luminosity, as observed by Reis (2015) for Pernambuco. Our results suggest the need for additional fieldwork to better understand the distribution and ecology of the genus *Riccia* in northeastern Brazil, since the species richness distribution is necessary to understand spatial patterns of biodiversity, to establish conservation strategies, or to predict future patterns of biodiversity under global change (Ricklefs 2004, Algar et al. 2009).

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Authors' Contributions

JS collected the data, JS, RF and DC identified the material and wrote the paper.

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